

Technical Field

The present invention relates generally to fluid powered diaphragm pumps and, in particular, to a control module for controlling the stroking of a diaphragm forming part of the fluid powered diaphragm pump.

Background Art

Diaphragm pumps are used in a wide variety of applications and are considered to be a positive displacement type pump. Diaphragm pumps are especially useful for pumping fluids that contain solid or semi-solid material which would adversely affect the operation of other types of positive displacement pumps, such as progressive cavity pumps.

A fluid powered diaphragm pump operates by controlled application of a fluid pressure against a diaphragm mounted within a pump housing. During a pump discharge stroke, the diaphragm exerts pressure upon fluid within the housing causing that fluid to be pumped from a housing outlet. On a suction or return stroke, the diaphragm is withdrawn to allow fluid to enter a housing inlet before a subsequent discharge stroke.

Prior art fluid powered diaphragm pumps utilize a variety of mechanisms for effecting the discharge and suction strokes. In some prior art pumps, compressed fluid is routed to a diaphragm chamber during the pump discharge stroke which applies a force against the diaphragm causing it to extend and force fluid out the pump discharge. On the suction stroke, the diaphragm chamber is vented and the diaphragm is urged in the opposite direction by either a mechanical spring or a fluid pressure operated cylinder or actuator.

Examples of prior pump designs are disclosed in U.S. Patent Nos. 4,621,990 and 4,856,969, both of which are owned by the assignee of the subject application and are hereby incorporated by reference. The '990 patent discloses a diaphragm pump using a spring to store energy during a discharge stroke which is utilized to effect the suction stroke. The '969 patent utilizes a fluid pressure operated cylinder to achieve the suction stroke. In the '969 patent, timers and other electronic controls are disclosed for controlling the suction and discharge strokes for the diaphragm pump.

Many prior art diaphragm controllers in current use today use fluid logic and associated fluid pressure circuitry to control operation of the pump. Many of these circuits rely on pressure differentials generated in valve control chambers to cause shifting of valve elements. Many of the current diaphragm pump controllers of this type suffer from a "stalling" or "centering" phenomena. When this phenomena occurs, the direction control valve becomes positioned such that it cannot distribute the input power to operate the pump. Manufacturers have attempted to solve this problem using various techniques. These attempts to solve the problem have not been completely successful.

#### Disclosure of Invention

The present invention provides a new and improved diaphragm pump and control system and method for controlling a diaphragm pump. In particular, a control module is disclosed for a diaphragm pump that is adaptable to a wide variety of diaphragm pumps. The control module controls the stroking of the pump and includes pressure regulators for adjusting the rate of stroke and sensors for ensuring that

full suction and discharge strokes are executed by the diaphragm pump. The control module is a self-contained unit and can be adapted to both new and old diaphragm pump designs.

5           According to the invention, the pump control includes a housing adapted to be mounted to the pump housing of a diaphragm pump and includes a passage for communicating fluid under pressure, i.e., pressurized air to a pumping chamber forming part of the diaphragm pump. A fluid  
10           pressure operated actuator is attached to the housing and includes an actuating member, preferably an actuating rod, operatively connected to the diaphragm. First and second end of stroke sensors are provided for sensing predetermined limits of movement for the actuating rod.

15           A direction control valve selectively directs fluid under pressure to the pumping chamber during a discharge stroke and to a retraction chamber forming part of the actuator during a suction stroke. A detent valve that is responsive to the end of stroke sensors controls the  
20           direction control valve and includes a valve element shiftable between first and second positions. The detent valve is maintained in a given position until it receives a fluid pressure signal generated by one of the end of stroke sensors.

25           According to a feature of the invention, first and second pressure regulators are provided for separately adjusting the fluid pressure applied to the pumping chamber and to the retraction chamber during a discharge stroke and suction stroke, respectively.

30           Other features of the pump control include a port that is connectable to a chamber forming part of the actuator which, when pressurized, urges the actuating rod in a

discharge stroke direction. In the preferred method of operation, this chamber is fed pressurized fluid whenever pressurized fluid is being fed to the pumping chamber.

5 According to another feature of the invention, the control module includes replaceable adapter members for adapting the pump control to pump housings of various configurations.

10 In the preferred and illustrated embodiment, the direction control valve, intermediate valve, module housing and regulator valves form a unitary subassembly. Fluid passages formed within the components are fluidly interconnected when these valve components are secured together.

15 The present invention also discloses a method for operating a diaphragm pump which includes providing an actuator, including an actuating member, i.e., actuator rod operatively coupled to the diaphragm. Fluid pressure is selectively applied to a pumping chamber to cause the diaphragm to move in a discharge direction. Movement of the  
20 actuating rod to a predetermined discharge position is sensed. A pressure differential is then generated across a detent control valve to cause it to change position. The operational state of the direction control valve is changed in response to a change in position of the detent valve.  
25 Upon a change in state, fluid pressure is then applied to a retraction chamber forming part of the actuator in order to move the actuating rod in a suction stroke direction. When the actuating rod reaches a predetermined suction stroke position, a second pressure differential is generated which  
30 shifts the detent valve to its initial position whereby fluid pressure to the retraction chamber is terminated and fluid pressure is again communicated to the pumping chamber.

According to a feature of the invention, the pressure regulators, which are used to control the pressure levels sent to the pumping chamber of the diaphragm pump and the retraction chamber of the actuator, are positioned downstream of the fluid pressure applied to the direction control valve. As a result, full line pressure is applied to the direction control valve, thus improving its operation because the pressure differentials that cause shifting of valve elements in both the direction control valve and detent valve are not affected or reduced by the pressure regulators. If the pressure regulators were positioned between the source of air pressure and the control module all fluid pressure applied to the module would be reduced by one or both pressure regulators and reduced performance could result especially at low pressures.

An object of the invention is to provide an improved control circuit scheme that will allow for the reliable and consistent operation of a device, such as a fluid power diaphragm pump. It is also an object of the present invention to provide a circuit having flexibility in its implementation which allows it to be adapted to a wide variety of fluid pressure operated diaphragm pumps.

An advantage of the disclosed invention is that it can be installed on existing hardware and utilizes many component parts from the original piece of equipment.

Additional features of the invention will become apparent and fuller understanding obtained by reading the following detailed description made in connection with the accompanying drawings.

#### Brief Description of Drawings

Figure 1 is a perspective view of a diaphragm pump and

control module constructed in accordance with a preferred embodiment of the invention;

Figure 2 is a perspective view of the control module constructed in accordance with the preferred embodiment of the invention;

Figure 3 is an exploded view of the control module shown in Figure 2;

Figure 4 is a side elevational view, partially in section, of the control module shown attached to a portion of a diaphragm pump that is shown schematically;

Figure 5 is a schematic representation of the control circuit forming part of the control module, including a schematic representation of a actuating rod forming part of the control module; and,

Figure 6 is another schematic representation of the circuit and fluid pressure control component forming part of the control module.

#### Best Mode for Carrying Out the Invention

Figure 1 illustrates a diaphragm pump assembly 10 that includes a diaphragm pump 12 and a control module 14 constructed in accordance with the preferred embodiment of the invention. The pump control module or controller 14 controls reciprocating movement of a diaphragm 16 that forms part of the diaphragm pump 12 and is schematically shown in Figure 4).

The diaphragm pump 12 may be conventional and includes a diaphragm housing 12a in which the flexible diaphragm 16 is mounted. As is known and referring also to Figure 4, the diaphragm 16 divides the diaphragm housing 12a into an upper chamber 16a and a lower chamber 16b (shown only in Figure 4). The lower chamber 16b is connected to a base Tee 20

(Figure 1) through which the pumpage or effluent flows. The inlet to the pump 12, indicated generally by the reference character 22 is defined at least in part by a conventional check valve 24 which operates to allow the pumpage to flow, substantially unrestricted, from an inlet flange 26 to the base Tee 20.

A pump discharge indicated generally by the reference character 28 is defined in part by a discharge check valve 30 which permits substantially unrestricted fluid flow from the base Tee 20 to a discharge flange 32 but inhibits reverse fluid flow from the discharge flange 32 to the base Tee 20.

The pump control module 14 effects vertical, reciprocating movement (as viewed in Figure 1) in the diaphragm 16 located within the diaphragm housing 12a (shown in Figure 4). As the diaphragm 16 is moved upwardly in what is usually termed a "suction stroke," material to be pumped is drawn into the base Tee 20 and lower chamber 16b of the diaphragm pump via the inlet check valve 24. Pumped material at the discharge flange 32 is inhibited from being drawn into the base Tee 20 by virtue of the discharge check valve 30. Following the suction stroke of the diaphragm, the control module or controller 14 effects downward movement of the diaphragm 16 which is usually termed a "discharge stroke". The downward movement of the diaphragm 16 forces pumpage material from the lower diaphragm chamber 16b into the base Tee 20 and out through the discharge check valve 30. The material being pumped is inhibited from flowing to the inlet flange 26 by virtue of the inlet check valve 24. As should now be understood, and which is also conventional, the reciprocating movement of the diaphragm 16 causes pumpage material to be conveyed under pressure from

the inlet flange 26 to the discharge flange 32.

The reciprocation or "stroking" of the diaphragm 16 is controlled by the pump control module 14. Referring to Figures 1-4, the pump control module 14, in the preferred embodiment, is fluid pressure operated and in the illustrated embodiment, is operated by air pressure.

Referring in particular to Figures 2 and 3, the control module 14 includes a fluid pressure operated actuator or cylinder 50 that includes an actuating rod 50a that is connected to the diaphragm 16 located within the pump's diaphragm housing 12a (the connection is schematically shown in Figure 4). As is conventional, the primary purpose of the cylinder 50 and associated actuating rod 50a is to retract the diaphragm 16, i.e., move it to its upper position as viewed in Figure 4. In short, the primary purpose of the cylinder 50 is to effect the "suction stroke" of the pump.

Referring in particular to Figure 3, the cylinder 50 is secured to an intermediate housing or bracket 60. An adapter 64 is secured to the underside of the intermediate bracket 60 by a plurality of bolts 66. The adapter 64 which is flange-like in construction is bolted to a pump flange 68 forming part of the diaphragm housing 12a (shown schematically in Figure 4). As seen in Figure 4, the actuating rod 50a extends through the intermediate bracket 60 and adapter 64 and is connected to a central portion of the diaphragm 16. The lower end of the actuating rod 50a may include a threaded segment adapted to threadedly engage the center of the diaphragm 16.

The intermediate bracket 60 mounts a pair of pressure regulators 72a, 72b, a direction control valve 74 and an intermediate valve 76. As will be explained, the

intermediate valve 76 provides a detent or lock function for the direction control valve 74.

When the intermediate valve 76, direction control valve 74, and pressure regulators 72a, 72b are bolted to the intermediate bracket 60, the necessary fluid communications between the components are established by porting and passages formed in the components.

The fluid pressure circuits that form part of the control module 14 are illustrated schematically in Figures 5 and 6. Referring to Figures 1-6, a source of air pressure which provides the motive force for the diaphragm 16 and the cylinder 50 is connected to an inlet port 80 forming part of the direction control valve 74. Referring to Figures 4 and 5, in the preferred and illustrated embodiment, the cylinder 50 includes upper and lower end-of-stroke sensors 86, 88 which directly or indirectly sense the extreme upper and lower positions of the actuating rod 50a that forms part of the cylinder 50. When the actuating rod 50a reaches its upper extreme of travel (as viewed in Figure 4) an upper piston surface 90a actuates a valve actuating pin 86a forming part of the end-of-stroke sensor 86.

In the construction shown in Figure 4, the illustrated cylinder 50 includes upper and lower piston heads 90a, 90b which are attached to or form part of the actuating rod 50a. Cylinders having alternate constructions may be used with the present invention and this invention should not be limited to the construction of the cylinder 50 shown in Figure 4. In particular, a cylinder may be used that includes only a single piston 90, as shown in Figures 5 and 6. In this type of cylinder, an upper surface 90a of the single piston 90, contacts and operates the actuating pin 86a when the actuating rod 50a reaches its uppermost

position.

In the preferred embodiment, the end-of-stroke sensors 86, 88 are normally closed, pneumatic valves. The upward movement of the actuating pin 86a shifts a valve element within the normally closed end-of-stroke sensor 86 to establish the fluid communication shown schematically in Figure 5 and allow fluid flow through the valve. In its unactuated position, the end-of-stroke sensor 86 blocks flow through the valve.

As seen in Figure 5, the source of fluid pressure (in this case air pressure) is communicated to the inlet port 80 that forms part of the direction control valve 74. It is also communicated to pilot pressure chambers 76a, 76b of the intermediate valve 76 via supply passages 94a, 94b. Supply pressure is also communicated to input ports 102, 104 forming part of end-of-stroke sensors 86, 88, respectively by branch supply passages 106, 108. Finally, supply pressure is also supplied to a supply port 110 of the intermediate valve 76 by a branch supply conduit 112.

The direction control valve 74 is also pilot pressure operated and includes opposed pilot pressure chambers 74a, 74b. As is conventional, a valve element within the direction control valve 74 shifts in response to differential pressures established in the pilot pressure chambers 74a, 74b. Similarly, a valve element forming part of the intermediate valve 76 is also shifted in response to differential pressures in the pilot pressure chambers 76a, 76b.

The operation of the control module 14 will now be explained. Figure 5 illustrates the states of the control system components and valves when the actuating rod 50a reaches its uppermost position (as viewed in Figure 5) and

has actuated the end-of-stroke sensor 86. As the actuating rod 50a reaches the end of its suction stroke (the upper extreme of movement for the actuating rod), the end-of-stroke sensor pin 86a is operated by the piston surface 90a (or the upper piston 90a-Figure 4) and moves a valve element within the end-of-stroke sensor 86 from its normally closed position to an open position at which the input port 102 is communicated with an atmospheric port 114. This immediately vents the supply line 106 to atmosphere thereby venting the pilot pressure chamber 76b of the intermediate valve 76. The supply line 94b that feeds both the pilot pressure chamber 76b and the supply port 102 of the end-of-stroke sensor 86 includes an orifice 146 sized to restrict the flow of air to the pilot pressure chamber 76b such that the rate at which the air is vented via the end of stroke sensor 86 is greater than the rate of replenishment air. As a result, a pressure substantially less than source pressure is created in the pilot pressure chamber 76b.

The left pilot pressure chamber 76a (as viewed in Figure 5) is maintained at source pressure via the branch supply line 94a and the closed position of the lower end-of-stroke sensor 88. In the closed position, supply pressure at the input port 104 is blocked from atmospheric port 118 forming part of the lower end-of-stroke sensor 88. This differential pressure established by the pilot pressure chambers 76a, 76b across the valve element of the intermediate valve 76 causes it to shift rightwardly and establish the fluid communication shown in Figure 5, which as will be explained causes a shift in the direction control valve 74.

In particular, a pilot pressure chamber signal passage 120 which is connected to the right pilot pressure chamber

74b of the directional control valve 74 is vented to an atmospheric port 126 of the intermediate valve 76. A pilot pressure chamber signal passage 122 which is connected to the left pilot pressure chamber 74a is communicated to source pressure via the intermediate valve 76 and branch supply passage 112. As a consequence, a differential pressure is established across the main control element of the direction control valve 74 causing it to shift rightwardly (as viewed in Figure 5) and establish the fluid pressure communications necessary to execute a discharge stroke in the diaphragm pump 12.

As seen in Figure 5, when the direction control valve 74 is shifted to the right, source pressure at the supply port 80 is connected to a pressure conduit 130. The pressure conduit or passage 130 communicates with the upper chamber 16a. When the upper chamber 16a is pressurized, the diaphragm 16 is urged downwardly and causes pumpage in the lower chamber 16b and base Tee 20 to be driven out the pump discharge 32 (see Figure 1). For some applications, the conduit 130 may also be connected to an upper chamber 136 of the cylinder 50 (shown in Figure 4) in order to create a downward force on the actuating rod 50a which is also applied to the diaphragm 16.

The passage 130 (which is shown schematically in Figure 5) is defined by passages and other structures formed in the control module 14. In particular, the passage 130 is defined in part by a passage 130a formed in the pressure regulator 72b and a passage 130b defined by the intermediate bracket 60. A cross drilled passage 130c communicates the passage segment 130b with a central region 130d defined by the adapter 64. The region 130d defines an opening through which the actuating rod 50a extends to connect with the

center of the diaphragm 16.

5 The passages 130a, 130b 130c are cross connected when control module 14 is assembled. O-ring seals 137 are used to seal the passage connections when the direction control valve 74, the pressure regulators 72a, 72b and intermediate bracket 60 are bolted together. The region 130d communicates with the upper chamber 16a and, thus, air delivered to the passages 130a, 130b, 130c and 130d provide air pressure to the upper diaphragm chamber 16a during a discharge stroke.

10 Similarly, the passage 142 (shown schematically in Figures 5 and 6) is defined by passage segments defined by the regulator valve 72 and intermediate bracket 60. A passage (not shown) formed in the intermediate bracket 60 is in fluid communication with the lower chamber 138 of the cylinder 50.

15 The cross drill passage 130c is normally sealed by a removable plug 139. For those applications, where the upper chamber 136 of the cylinder 50 is to be pressurized during a discharge stroke, the cross drill passage 130c is connected to the upper cylinder chamber 136. In particular, the plug 139 is removed and replaced by a fluid pressure fitting. An upper cylinder head 141 of the cylinder 50 includes a port 143 that communicates with the upper chamber 136. The port 143 is normally open to atmosphere if the upper chamber 136 is not to be pressurized. To achieve pressurization of the upper chamber 136 during a discharge stroke, a conduit shown schematically as 145 is connected between cross drill passage 130c and the port 143.

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25  
30 Concurrently with the pressurization of the upper diaphragm chamber 16a, a lower piston chamber 138 of the cylinder 50 (shown in Figure 3), is vented to an atmosphere

port 140 on the direction control valve 74 via pressure conduit 142. The depressurization of the lower cylinder chamber 138 eliminates the retract force exerted on the actuating rod 50a and allows the diaphragm 16 to move  
5 downwardly with a force determined by the air pressure in the upper chamber 16a (and the upper cylinder chamber 136 if pressurized) and effect a discharge stroke.

As the actuating rod 50a moves downwardly, the normally closed valve element forming part of the upper end-of-stroke sensor 86 returns to its normally closed position, thus  
10 repressurizing the right pilot pressure chamber 76a of the intermediate valve 76. Since both pilot pressure chambers 76a, 76b are now at source pressure, i.e., balanced, the valve element remains in position shown in Figure 5.

Turning now to Figure 6, as the actuating rod 50a  
15 reaches the end of its discharge stroke, the lower piston surface 90b (or lower piston surface in a single piston cylinder 90b) actuates the lower end-of-stroke sensor 88 and moves its associated valve element from its normally closed position to an open position at which its input port 104 is  
20 communicated to atmosphere via port 118. The input port 104 of the end-of-stroke sensor 88 is connected to the pressure supply conduit 94a via branch passage 108; the supply passage 94a also communicates source pressure to the left  
25 pilot pressure chamber 76 of the intermediate valve 76. The supply conduit 94a includes an orifice 116 designed to limit the rate at which air pressure can flow to the pilot pressure chamber 76a. Consequently, the venting of the  
30 branch passage 94a that is connected to the pilot pressure chamber 76a causes the pressure in the pilot pressure chamber to fall substantially below source pressure thus establishing a differential across the valve element in the

intermediate valve 76. This differential shifts the valve element leftwardly (as viewed in Figure 6) and establishes the fluid pressure communications shown in Figure 6.

5 In particular, the left pilot pressure chamber 74a of the direction valve is vented to atmosphere via the passage 122 which is connected to an atmospheric port 150 on the intermediate valve 76. Concurrently, source pressure is communicated to the right pressure pilot chamber 74b of the direction control valve 74 by means of the supply passage 10 120 which is connected to the supply conduit 110 via the intermediate valve 76. This establishes a pressure differential across the valve element of the direction control valve 74 causing it to move leftwardly as viewed in Figure 6 and establish the illustrated communications. In 15 particular, source pressure is communicated to the lower chamber 138 of the cylinder 50 via the supply passage 142. The upper piston chamber 136 and upper diaphragm chamber 16a is vented to atmosphere via supply passage 130 which is connected to an atmospheric port 156 on the direction 20 control valve 74.

In Figure 3 mufflers/filters attached to the atmospheric ports 140, 156 of the direction control valve 74 are shown and indicated by the reference characters 140a and 156a, respectively.

25 As should be apparent, the actuating rod 50a and hence diaphragm 16 will reciprocate vertically as the direction control valve 74 shifts the application of source pressure to the actuating rod retraction chamber 138 from the upper diaphragm chamber 16a. The end-stroke-sensors 86, 88 ensure 30 that the actuating rod 50a travels to its extremes of movement rather than changing direction when in an intermediate position as is the case with some prior art

controllers which switch based on timers. With this disclosed control module apparatus, extremely precise metering of fluid pumped by the pump assembly 12 can be maintained. This is due to the fact that the diaphragm pump 12 is a positive displacement pump and a full stroke of the diaphragm 16 will pump a relatively precise amount of pumpage from the pump inlet 22 to the pump outlet 28.

In most applications, the air pressure necessary to effect a discharge stroke is substantially greater than the air pressure needed to retract the diaphragm in order to perform a suction stroke. According to a feature of the invention, the discharge stroke pressure is separately adjustable from the suction stroke pressure. Turning to Figure 5, as explained above, the supply passage 130 supplies pressure to the upper diaphragm chamber 16a during the discharge stroke (and may also supply pressure to the upper cylinder chamber 136). The adjustable pressure regulator 72b determines the pressure that is delivered to the upper chamber 16a of the diaphragm housing 12a (see Figure 4) by the supply passage 130.

As explained above, the supply passage 142 supplies pressure to the lower chamber 138 of the cylinder 50 during the suction stroke in order to move the diaphragm upwardly. The supply line 142 includes a separate, adjustable regulator 72a by which the maximum pressure delivered to the lower chamber 138 is determined.

The adjustable regulators 72a, 72b can be used to adjust the stroke rate of the pump and, in fact, can be adjusted so that the discharge stroke rate and suction stroke rates are different. For some applications, such as heavy slurries, it may be desirable to have a suction stroke rate that is slower than the discharge stroke rate.

As also explained above, when the supply passage 130 is supplying air pressure, the passage 142 is used as a vent passage and vice versa. In order to facilitate venting through the passages, respective check valves 160, 162 are used to bypass the pressure regulator 72a, 72b when the passages 142, 130 are venting air pressure, respectively.

It should be noted here that the illustrated pressure regulators 72a, 72b are adjusted by manually operated adjusters 164, 166. The invention, however, contemplates other types of adjustable pressure regulators, such as remotely controlled, pneumatically and electrically operated pressure regulators.

As indicated above, the intermediate valve 76 provides a detent or lock function for the directional control valve 74 which inhibits the occurrence of "centering" or "stalling" of the actuator 50. The intermediate valve 76 isolates the direction control valve 74 from partial signals that may be generated by one or both of the end-of-stroke sensors 86, 88. These partial signals may be generated when the piston 90 reaches one of its limits of travel and initially contacts the actuating pin of one of the end of stroke sensors. The initial contact with the actuating pin, causes the intermediate valve to effect a shift in the direction control valve 74. The direction control valve 74 will remain in its shifted position until the opposite end-of-stroke sensor is actuated. Under some operating conditions, pressure fluctuations in the diaphragm chamber may cause the piston to "bounce" and reactuate the end of stroke sensor. With the present invention, this "bounce" will not cause a shift in the direction control valve 74. Only actuation of the opposite end-of-stroke sensor can effect a shift in the directional control valve. As a

consequence, the occurrence of "stalling" or "centering" is substantially eliminated.

Another advantage of the present invention is provided by the position of the pressure regulators in the fluid circuit. As seen best in Figures 5 and 6, the directional control valve 74 and the intermediate valve 72 are located upstream of the air pressure regulators 72a, 72b. As a result, the valves 74, 76 are always connected to full line pressure to assure reliable operation. In some control systems where an "upstream" pressure regulator or regulators are used to adjust the timing of the suction and/or discharge strokes, "stalling" or "centering" may occur. This is due to the reduced operating pressure that results from pressure regulators upstream of the valves that are adjusted to produce lower pressures.

The disclosed control module can be easily adapted to a variety of diaphragm pumps both new and old. The use of a separate adapter 64 by which the control module 14 is mounted to an existing flange of the diaphragm pump, allows the same control module to be used on diverse diaphragm pumps. Only the adapter 64 needs to be sized and configured for the diaphragm pump flange 68 (see Figure 4). In addition, differently sized cylinders 50 can be easily fitted to the same intermediate bracket 60 in order to accommodate the stroke distance for a particular pump.

Although the invention has been described with a certain degree of particularity, it should be understood that those skilled in the art can make various changes to it without departing from the spirit or scope of the invention as hereinafter claimed.